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FORGING AND STAMPING (SELECTED ARTICLES),(U)
JAN 79 S Z FIGLIN, V V BOYTSOV, Y P SOGRISHIN

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FORGING AND STAMPING
(SELECTED ARTICLES)

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

ADVANTAGES OF HOT ISOTHERMAL STAMPING

S. Z. Figlin, V. V. Boytsov, A. V. Bakharev, Yu. G. Kalpin

The article present features of a new method of high-temperature pressure treatment of metals which were exposed as a result of experimental investigations - deforming in the tool with heating up to the temperature of deformation. In this case, the possibility of cooling a billet is eliminated, and conditions for deformation can be considered close to isothermal.

The process of isothermal stamping was studied basically on titanium alloys which possess low heat conductivity. Their deforming under normal conditions is distinguished by sharp nonuniformity of the temperature field of the billet and, as a result, a great irregularity of deformation [1]. As the equipment for isothermal deforming, we used hydraulic presses with regulated slide bar rate. The stamps were heated in the block mounted in the working zone of the press up to the deformation temperature. A principle diagram of the block is given in Figure 1*.

Footnote * - S. Z. Figlin, V. V. Boytsov, T. V. Levchenko. Stamp for hot deforming. Author's certificate No. 315499, bulletin "Izobretenia promyshlennye obraztsy i tovarnye znaki", 1971, No. 29.

The block has thermal insulation of the working space consisting of
of bed plates 1 and 8 and movable 2 and immovable 7 shells. In the process of work, the movable shell tightly enters the immovable; loading and unloading of billets is accomplished through the window 9 in the immovable shell. Thus, in the upper position of the slide bar, heat insulation does not break down in the working space. Stamps 3 and 5 are heated with the aid of air-cooled inductors 4 and 6 which operate on an industrial frequency.

As a result of using heat insulation constructed in this manner, high temperature (800-1050°) of the working zone, which is necessary for isothermal stamping, is maintained in the course of deformation. The stamps and sub-stamp plates are made of cast heat-resistant alloys on a nickel base (ZhS6-K).

Technological lubrication of titanium billets is borosilicate glass, applied on the surface of a cold billet in the form of a water suspension. In contrast to normal conditions, with isothermal deformation the glass lubrication is found in the viscous state and forms a thin dividing layer between the billet and the tool. The contact friction factor, determined by the conical striker method, is 0.04-0.06 with the use of glass lubrication. With settling of titanium samples without lubrication, the friction factor approximates 0.5.

A substantial decrease in contact friction in combination with uniformity of the temperature field of the billet causes a sharp increase in evennness of deformation. The difference in the character of deformation is particularly perceptible with stamping of parts with large ratio of surface area to volume. So, for example, the structure of a billet obtained on a crank press (graphite-oil lubri-

cation, temperature of heating the stamp 250°C, temperature of heating the billets 930°C), has a clearly expressed dead zone in the areas of contact with the tool. The structure of billets stamped on a hydraulic press (glass-lubrication, temperature of heating the stamps(930°C) is practically uniform along the entire cross section of the billet.

Another advantage of isothermal deformation is the increase in plasticity of the treated material, which is connected with a fuller flow of the weakening processes, and also diffusion and "healing" of microcracks with decreased deformation rates. Figure 2 shows samples made of alloy VTZ-1 which ruptured at 850°C and at deformation rates of $14 \cdot 10^{-4}$, $28 \cdot 10^{-4}$, and $112 \cdot 10^{-4}$ sec^{-1}. With an eight-fold decrease in this rate, the relative lengthening increases by 28-30%, and the relative narrowing reaches 100%. Figure 3 shows samples made of alloy VT8 with initial dimensions of diameter 15x20 mm, subjected to settling in the end at 780°C and deformation rates of 0.15 and 0.005 sec^{-1}. As we can see from Figure 3, with a decrease in the rate by 30 times, deformation of the sample increases remarkably (with one an and the same force of deforming) and billets without breakdown in completeness of their side surface are obtained.

Studies have shown that the maximum, corresponding to the appearance of the first crack, value of deformation of titanium alloys increases with an increase in temperature. In the range of deformation rates 0.02-0.1 sec^{-1}, beginning from 800°C for alloy VTZ-1 and 850°C for alloy VT8, plasticity becomes practically limitless. A sample, in one pass of the press, settles with a degree of deformation of 95-98% without destruction.

The creation of isothermal conditions opens new possibilities with deforming of low-plasticity materials. Thus, with settling of billets made of stellite (900°C, deformation rate 0.005 sec^{-1}), we succeeded in acquiring deformation of 60% without destruction of the billet. Pressed bars made of cast iron SCh 19-32 (920°C, drawing 2, deformation rate 0.1-2.5 mm/sec) had uniformly clean surface.

With deforming in isothermal conditions, required forces are substantially reduced. This is fostered by the absence of partial cooling of the billet and increase in flow time of the softening processes with a decrease in deformation rate. Figure 4 shows the change in specific force of settling of titanium samples under normal conditions on the crank press of the press (curve 1) and under isothermal conditions on the hydraulic press (curve 2). Samples made of alloy VTZ-1 with dimensions diameter 15x20 mm were deformed without lubrication at 900°C. Up to 60% deformation, when partial cooling of the ends of a billet does not prove to be a substantial influence on the deforming force, the ratio of specific forces with stamping on the crank press and under conditions of isothermal stamping equals 2. With a decrease in the thickness of the billet, its partial cooling increases this difference noticeably. With 80% deformation, the ratio of specific forces is 2.8.

A decrease in deforming force with isothermal stamping is also a result of more uniform deformation and an increase in efficiency of glass lubrication. Here, the influence of each of the examined factors is different depending on the configuration of the part, its material, conditions of deformation, etc.

In individual cases, the force of isothermal stamping can differ greatly from a force required for normal deforming. For example, with isothermal stamping of billets made of thin and wide fabrics made of alloys VTZ-1 and VT8, the average specific force does not exceed 25-30 kgf/mm^2; here, we succeed in stamping the fabric with a ratio of width to thickness on the order of 25. With stamping of similar parts under normal conditions, the specific forces are 80-100 kgf/mm^2, but even with these loads the ratio of width of the fabric to thickness does not exceed 15. A similar picture is observed also with stamping of billets made of heat-proof steels, for example Kh17N2. According to the data of a foreign firm, isothermal stamping of a precise billet of a disk made of titanium alloy can give a gain in force of 10 times [2].

Since the force and work of deformation are lowered, the amount of fuel given off in the billets decreases correspondingly. Moreover, uniformity of deformation increases, as a result of which the fuel given off is distributed more uniformly. This is particularly important for titanium alloys whose structure and properties react to an increase in temperature of billets in the process of stamping [3].

Under isothermal conditions, we can stamp billets which are complex with respect to configuration. Figure 5 shows parts which are stamped in one pass of the press. A billet of the sector (Fig. 5,a) has narrow edges between the central nipple and external ribs. The minimum thickness of the edge is 1 mm, stamping angle 3°. The stamped billet is removed from the stamp by the lower extruder. The billet of the cantilever (Fig. 5,b) has a thickness of the fabric of 2.5 mm and an area in the plan of about 1200 mm^2. The part with two projections

(Fig. 5,c) was stamped in a closed stamp with the lower extruder. The height of the projections is 14 mm with a thickness of 2 mm. A bushing obtained by inverse pressing (see Fig. 5,d) has a wall with a thickness of 1 mm, and an external diameter of 47 mm.

As we can see from Figure 5, for billets, complex configuration, narrow edges, thin fabrics, and a changing value of the transverse cross section are all typical. Nevertheless, the die impressions of the stamp are filled up well, and there are no scratches or cracks on the billets. The cleanliness of the billets' surface after sand-blasting cleaning corresponds to $\nabla 5$-$\nabla 6$, which, in a number of cases, permits eliminating mechanical treatment.

The specifics of the examined process find their reflection in the structure of the stamping equipment. Heating of the stamps up to a high temperature hinders a firm fastening of the stamp-attachments to the heating block. Therefore, in the majority of cases, it is expedient to make the guiding columns or joints in the attachments. Here, the use of columns is preferable, since columns occupy a smaller useful area of the stamp's mirror, they are made easily, and mounting and replacing them is easy. In order to avoid guides for the columns, the ratio of the height of the projecting cylindrical part to the diameter must be no more than 1.5. The two-sided gap between the column and the stamp must be from 0.08 to 0.2 mm (depending on the diameter of the column).

In connection with the fact that the temperature of the billeta and the stamp in the process of deforming is practically identical, the dimensions of the stamps' grooves are set without shrinkage. However, in individual cases (for dimensions of more than 200 mm or with stamping billets with increased accuracy) we must consider shrinkage

due to the difference in coefficients of linear expansion of materials of the stamp and the billet 0.3%.

We must keep in mind that viscosity of glass lubrication at 800-1000°C is substantial (15-25 thousand poise). Therefore, glass lubrication almost glues the billet to the groove of the stamp, and for removing the latter it is expedient to envision fins.

The character of wear of the stamp changes. Under isothermal conditions, there is practically no wearing of the die impression which is typical for stamping; the absence of noticeable heat fluctuations prevents the appearance of thermal-erosion cracks. With isothermal deforming in stamps made of cast heat-resistant alloys, the necessity to restore the stamps causes sagging of the die impression. It was established that after 400-600 cycles, sagging was 0.1-0.15 mm. With casting of stamps with a finished die impression, the tool which is made from expensive cast heat-resistant alloys is made much less expensive.

The absence of thermal shocks, the static application of load makes possible the use, for making attachments, of such high-strength but friable materials as metal ceramics, powdered ceramic materials, etc.

Thus, got stamping of metals and alloys under isothermal conditions is a perspective process in the pressure treatment of metals.

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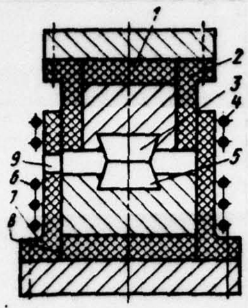

Figure 1. Block diagram for isothermal stamping.

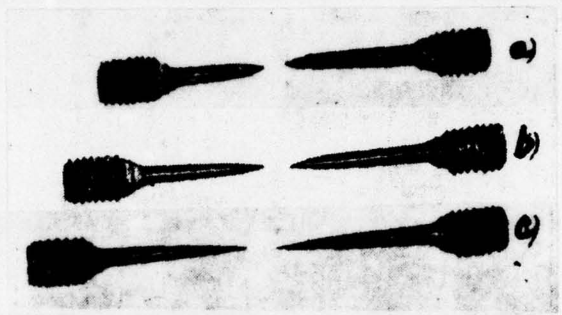

Figure 2. Samples of alloy VTZ-1, ruptured at various speeds of deformation (850°C); a - $112 \cdot 10^{-4}$ sec^{-1}; b - $28 \cdot 10^{-4}$ sec^{-1}; c - $11 \cdot 10^{-4}$ sec^{-1}.

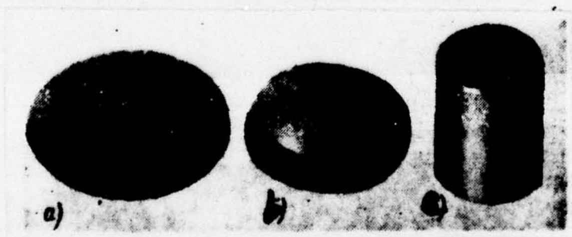

Figure 3. Samples of alloy VT8 after settling with various deformation rates (750°C): a - speed 0.005 sec^{-1}; b - speed 0.15 sec^{-1}; c - initial sample.

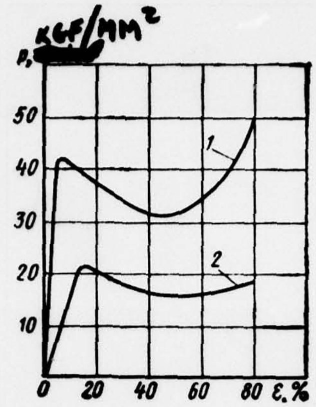

Figure 4. Dependence of specific force of settling of titanium samples on the degree of deformation: 1 - deformation in normal conditions on a crank press; 2 - deformation in isothermal conditions on a hydraulic press (900°C).

Figure 5. Billets of titanium alloys stamped under isothermal conditions: a - sector; b - cantilever; c - part with projections; d - bushing.

STAMPING TITANIUM ALLOYS ON A HIGH-SPEED HAMMER

Yu. P. Sogrishin, L. G. Grishin, G. G. Gur'yanov, F. V. Tulyankin, I. S. Makarov.

One of the basic questions of making precision billets with thin elements made of titanium alloys is the selection of the temperature-speed mode which will ensure high plasticity of the alloy in the process of deformation and sufficient mechanical properties of the deformed metal.

For the majority of titanium alloys with stamping on normal equipment, an increase in plasticity is achieved with a deformation temperature within the limits of the β-region. However, in this case, the mechanical characteristics of the forgings done are decreased. Therefore, β-stamping requires thermomechanical modes with which satisfactory shaping of forgings is combined with ensuring the required mechanical properties [1, 2, 3].

As experiments have shown, stamping on high-speed hammers in the β-region obtains precision forgings with satisfactory properties of the deformed metal. On the high-speed hammer SBM20* [4] made of titanium alloys VT5-1 and VT3-1 we stamped forgings of hemispheres,

a disk, and a cup (Fig. 1). Conditions for deforming forgings are shown in Table 1. Stamps were heated to 300°C and lubricated by spraying a water-graphite mixture. Billets were made from preliminarily forged bars machined on a lathe with roughness of the surface ∇3 and covered with glass lubricant No. 36. The glass lubricant was prepared in the form of a water suspension of glass-powder with an addition of casein glue and applied by spraying. After drying, the billets were heated in a high-temperature furnace with an accuracy of ±10°C. Time of heating was selected from calculation at 30 sec. for 1 mm of cross section of the initial billet.

The basic parts of closed-type stamps were made from steel 4Kh5V2FS with heat treatment up to HRC 46-48. In the die for making hemispheres, undercutting was accomplished which prevented fitting the forgings on the top die and eliminated upward jump of forgings in the stamp and deformation of it with repeated strikes.

The hemisphere was stamped from a cylindrical billet with a diameter of 80 mm. We obtained forgings with walls with a thickness of 8, 6, and 4 mm. Good shaping of the forgings with a wall of 4 mm was achieved with specific forces of 24-30 kgf/mm^2.

Forgings of disks were stamped with settling of cylindrical billets with discharge of metal in the ringed cavity with shaping of the rim. There was particular interest in studying the possibilities of acquiring a thin fabric, and also filling the ringed cavity of the rim under conditions of single-shock stamping. Deformation was conducted in three stages with gradual thickening of the rim with corresponding thinning of the fabric. The results of the investigation showed the possibility of good shaping of the fim with a width of

11.5 mm and a thickness of the fabric of up to 3.5 mm. Full shaping of the forging was achieved with specific forces 29-35 kgf/mm^2.

We observed a discrepancy of the results obtained with similar experiments described in the literature. Cases of formation of clamps with respect to the thickened external edge of the forging with single-shock stamping of a disk on a high-speed hammer are known [5,6]. This defect was successfully eliminated by introducing additional operation. The absence of a clamp can explain the difference in geometric parameters of the compared discs and the better selection of technological lubricants.

Cup forgings were stamped according to the same scheme as the disks, with specific forces 32-36 kgf/mm^2.

Figure 2 shows the macrostructure of forgings. We can see well the influence of temperature of deformation: the structure of forgings acquired in α- and $\alpha+\beta$-regions are more fine-grained and uniform than in samples deformed in the region of β-temperatures. Also visible on the microphotograph of the cup are zones of braking and intensive flow of metal, somewhat differing with respect to grain size. Figure 3 shows microstructures taken from two places on the disk. For $\alpha+\beta$-temperature, the grain size corresponds to 2-3 balls, and for β-temperature - 3-4 balls on a ten-ball scale.

The mechanical properties of forgings (average from 3-6 tests) of a hemisphere and cup were determined on tensile-test samples with a diameter of 5 mm (all samples were 5-fold) and shock samples (Table 2). For all temperatures of stamping, the spread of strength characteristics did not exceed 5%, and the characteristics of relative elongation and narrowing differed by not more than 1.2 times

(exceptions are the characteristics of narrowing on samples cut from the cup: here, we observe a 1.5 spread of indicators). An analysis of the data in Table 2 shows that the strength and plasticity characteristics of transverse samples made of alloy VT5-1 are practically identical in the α- and β-regions of stamping temperatures. Plasticity of longitudinal samples in the β-region was somewhat lower. The mechanical properties of alloy VT3-1 with stamping in the β-region are somewhat lower than in the region of α+β-temperatures. Regarding the impact strength, here there is a reverse dependence: stamping in the -region gives better results. In works [5,6], we noted the possibility of acquiring high mechanical properties with deformation of titanium alloys on high-speed hammers in the α+β- and β-regions. A case is described of stamping a disk where, exceeding the temperature for an interval of polymorphic conversion, we succeeded in improving the obtained macrostructure, eliminating traces of overheating which were observed at a lower temperature. A comparison of the mechanical properties and fatigue strength of samples cut from forgings obtained by normal stamping and by high-speed stamping of alloys JMJ679 (close to the VT3-1 in composition) and Khilit 50 showed that with high-speed stamping the properties were not lower than with normal stamping, and were even higher according to some indicators [5].

An explanation of the reasons for acquiring high mechanical properties of titanium alloys with their deformation on high-speed hammers is connected with the specifics of operation of the latter, which ensures acquisition of thinner structures [8,9]. First of all, one-shock stamping, typical for high-speed hammers, ensures high degrees of deformation (exceeding 30%), which are necessary for acquiring

a good structure of titanium alloys [7]. Secondly, the small time for deformation and rapid cooling in the stamp of thin cross sections of forgings do not give the possibilities of developing by processes of recrystallization, which ensures fixation of the deformed structure.

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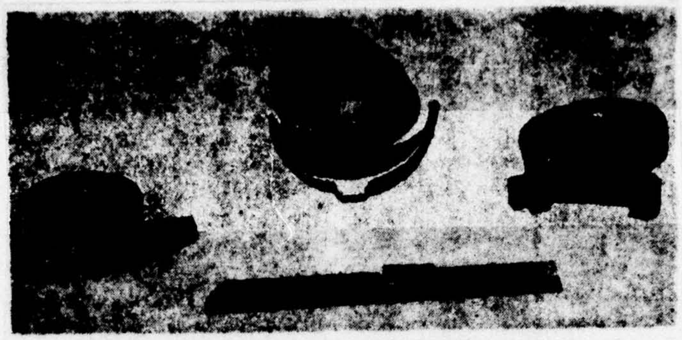

Figure 1. Forgings of cup (VT3-1), hemisphere (VT5-1) and disk (VT3-1)

1 Поковка	2 Материал	3 Температура, в °С	4 Начальная скорость соударения в м/сек	5 Удельные [illegible]
6 Полусфера	ВТ5-1 9	960	19—21	24 30
7 Диск	ВТ3-1 10	950	20—21	29 35
8 Чашка	ВТ3-1 10	950	14—15	32 36

Table 1. Conditions for shape-formation of forgings. Key: 1 - forging; 2 - material; 3 - temperature, °C; 4 - initial speed of shocks, m/sec; 5 - specific forces, kgf/mm^2; 6 - hemisphere; 7 - disk; 8 - cup; 9 - VT5-1; 10 - VT3-1.

Figure 2. Macrostructures of forgings of cup (a,b), hemisphere (c,d), and disk (e,f): a,c,e - structures with stamping in β-region; b,d,f - structures with stamping in α- and α+β-regions.

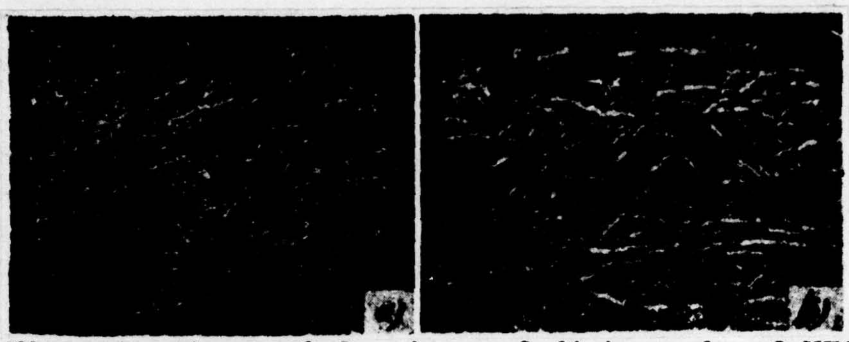

Figure 3. Microstructure of forgings of disks made of VT3-1 with stamping in the β-region: a - rim; b - hub.

Table 2. Mechanical properties of samples after annealing. Key: 1 - forging; 2 - material; 3 - region of deformation; 4 - type of sample; 5 - mechanical properties; 6 - σ_b in kgf/mm^2; 7 - σ_S in kgf/mm^2.

8 - δ in %; 9 - ϕ in %; 10 - a_k in kgf·m/cm^2; 11 - hemisphere; 12 - disk; 13 - cup; 14 - VT5-1; 15 - VT3-1; 16 - longitudinal; 17 - transverse; 18 - chord.

1 Поковка	2 Материал	3 Область деформации	4 Тип образца	5 Механические свойства				
				6 σ_b в кгс/мм²	7 σ_S в кгс/мм²	8 δ в %	9 ψ в %	10 a_k в кгс·м/см²
11 Полусфера	14 ВТ5-1	α	Продольный	89,3	86,7	15,2	45,8	—
			Поперечный	87,5	84,8	15,8	44,2	—
		β	Продольный	89,5	86,8	12,8	40,6	—
			Поперечный	87,5	83,0	15,8	46,2	—
12 Диск	15 ВТ3-1	α+β	18 Хордовый	110,1	108,0	13,7	39,7	4,38
		β		107,5	104,5	12,7	35,2	5,62
13 Чашка	15 ВТ3-1	α+β	Хордовый	113,9	111,0	13,4	35,7	—
			Поперечный	108,9	107,5	13,3	36,0	—
		β	Хордовый	112,8	109,5	11,6	31,5	—
			Поперечный	106,3	102,6	11,4	23,8	—

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C510 AIR MOBILITY R&D LAB/FIO	1	E410 ADTC	1
C513 PICATINNY ARSENAL	1	FTD	
C535 AVIATION SYS COMD	1	CCN	1
C591 FSTC	5	ASD/FTD/NIIS	3
C619 MIA REDSTONE	1	NIA/PHS	1
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